REMARKS

Claims 1-52 are pending. By this Preliminary Amendment, the specification is amended. Prompt and favorable examination on the merits is respectfully requested.

The attached Appendix includes marked-up copies of each rewritten paragraph (37 C.F.R. 1.121(b)(iii)).

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Attachment:
Appendix

Date: May 29, 2001

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APPENDIX

Changes to Specification:

The following are marked-up versions of the amended paragraphs:

Page 1, lines 13-22:

In a typical exposure apparatus for making micro devices such as semiconductor device, imag~~e-pickup~~ing picking device, liquid crystal display device, and thin film magnetic head, a beam emitted from a light source is incident on a micro fly's eye lens, and a secondary light source composed of a number of light sources is formed on the image-side focal plane thereof. Beams from the secondary light source are made incident on a condenser lens after being restricted by an aperture stop disposed near the image-side focal plane of the micro fly~~'~~'s eye lens.

Page 1, lines 23-26 and Page 2, lines 1-7:

The ~~b~~Beams collected by the condenser lens illuminate, in a superimposing manner, a mask formed with a predetermined pattern. The light transmitted through the pattern of mask forms an image on a photosensitive substrate by way of a projection optical system. Thus, a mask pattern is projected (transferred) onto the photosensitive substrate. The pattern formed in the mask is highly integrated. As a consequence, for accurately transferring this fine pattern onto a photosensitive substrate, it is indispensable that a uniform illuminance distribution be obtained on the photosensitive substrate.

Page 2, lines 8-14:

The micro fly~~'~~'s eye lens is a wavefront dividing type optical integrator composed of a number of micro lenses densely arranged in a matrix. In general, the micro fly~~'~~'s eye lens is constructed by etching a plane-parallel glass sheet, for example, so as to form a micro lens group. Here, each micro lens constituting the micro fly~~'~~'s eye lens is smaller than each lens element constituting a fly's eye lens.

Page 2, lines 15-23:

SUMMARY OF THE INVENTION

As mentioned above, it is indispensable for a photolith~~ograp~~grahic exposure apparatus for transferring a fine pattern onto a photosensitive substrate to yield a uniform illuminance distribution on the mask and/or on the photosensitive substrate. ~~Therefore, f~~For reducing the unevenness in illuminance, it has been desired to increase the number of micro lenses (micro optical elements) constituting the micro fly's eye lens(micro fly's eye ~~lens~~optical member), i.e., to increase the number of divisions of wavefront.

Page 2, lines 24-26 and Page 3, lines 1-6:

On the other hand, when making a micro fly's eye lens by etching and the like, the glass sheet is harder to etch deeply, and the making will be easier if the size of each micro lens is made smaller. However, simply reducing the size of each micro lens is disadvantageous in that illuminance decreases by the amount of diffraction limit with respect to the entrance surface of each micro lens in marginal areas of an illumination field formed on a surface to be irradiated which is optically conjugate with the entrance surface.

Page 3, lines 7-15:

It is an object of the present invention to provide a wavefront dividing type optical integrator which can yield a uniform illuminance distribution substantially over the whole illumination field formed thereby even when the size of each micro lens is made smaller so as to set a large number of wavefront divisions; an illumination optical apparatus comprising this optical integrator; and a photolith~~ograp~~grahic exposure apparatus and observation apparatus comprising this illumination optical apparatus.

Page 3, lines 16-26 and Page 4, lines 1-7:

The optical integrator in accordance with a first aspect of the present invention is a wavefront dividing type optical integrator, having a number of micro lenses(micro optical

elements) arranged two-dimensionally, for forming a number of light sources by dividing a wavefront of an incident beam; each micro lens having a rectangular entrance surface and a rectangular exit surface, and satisfying at least one of the following conditions:

$$(d_1/2)(D_1/2)/(\lambda \cdot f) \geq 3.05$$

$$(d_2/2)(D_2/2)/(\lambda \cdot f) \geq 3.05$$

where f is the focal length of each micro lens, d_1 is the length of one side of the entrance surface of each micro lens, d_2 is the length of the other side of the entrance surface of each micro lens, D_1 is the length of the side of exit surface in each micro lens corresponding to the one side of entrance surface, D_2 is the length of the side of exit surface in each micro lens corresponding to the other side of entrance surface, and ë is the wavelength of the incident beam.

Page 4, lines 14-26 and Page 5, lines 1-4:

The optical integrator in accordance with a second aspect of the present invention is a wavefront dividing type optical integrator, having a number of micro lenses(micro optical elements) arranged two-dimensionally, for forming a number of light sources by dividing a wavefront of an incident beam; each micro lens having a rectangular entrance surface and a circular or regular hexagonal exit surface, and satisfying at least one of the following conditions:

$$(d_1/2)(D/2)/(\lambda \cdot f) \geq 3.05$$

$$(d_2/2)(D/2)/(\lambda \cdot f) \geq 3.05$$

where f is the focal length of each micro lens, d_1 is the length of one side of the entrance surface of each micro lens, d_2 is the length of the other side of the entrance surface of each micro lens, D is the diameter of the circular exit surface or the diameter of a circle

circumscribing the regular hexagonal exit surface of each micro lens, and ë is the wavelength of the incident beam.

Page 5, lines 11-22:

The optical integrator in accordance with a third aspect of the present invention is a wavefront dividing type optical integrator, having a number of micro lenses(micro optical elements) arranged two-dimensionally, for forming a number of light sources by dividing a wavefront of an incident beam; each micro lens having a circular entrance surface with a diameter of d or a regular hexagonal entrance surface inscribed in a circle having a diameter of d, and satisfying the following condition:

$$(d_1/2)2/(\lambda \cdot f) \geq 3.05$$

where f is the focal length of each micro lens, and ë is the wavelength of the incident beam.

Page 5, lines 23-26 and Page 6, lines 1-9:

The illumination optical apparatus in accordance with a fourth aspect of the present invention is an illumination optical apparatus for illuminating a surface to be irradiated according to a beam from a light source, the illumination optical apparatus comprising the optical integrator, disposed in an optical path between the light source and the surface to be irradiated, for forming a number of light sources according to a ~~beam fro~~luminous beam the light source; and a light-guiding optical system, disposed in an optical path between the optical integrator and the surface to be irradiated, for guiding beams from a number of light sources formed by the optical integrator to the surface to be irradiated.

Page 6, lines 10-24:

In the illumination optical apparatus, the light-guiding optical system may comprise a condenser optical system, disposed in the optical path between the optical integrator and the surface to be irradiated, for co~~llect~~ndensing beams from a number of light sources formed by

the optical integrator so as to form an illumination field in a superimposing manner; an image forming optical system, disposed in an optical path between the condenser optical system and the surface to be irradiated, for forming an image of the illumination field near the surface to be irradiated according to a beam from the illumination field; and an aperture stop, disposed in an optical path of the image forming optical system at a position substantially optically conjugate with a position where the light sources are formed, for blocking an unnecessary beam.

Page 6, lines 24-26 and Page 7, lines 1-18:

In the illumination optical apparatus, each micro lens (micro optical element) in the optical integrator may have at least one refractive surface formed into an aspheric form which is symmetrical about an axis parallel to a reference optical axis in order to attain a substantially uniform illuminance on the surface to be irradiated. If an aspheric surface is introduced into each micro lens element in the optical integrator as such, then the number of parameters in terms of optical designing increases, which makes it easier to yield a desirable design solution, whereby the degree of freedom in design can be improved from the viewpoint of aberration correction in particular. Therefore, in the optical integrator, not only the occurrence of spherical aberration is favorably suppressed, but also the sine condition is substantially satisfied, whereby the occurrence of coma can be suppressed favorably. As a result, unevenness in illumination can favorably be restrained from occurring due to the optical integrator as multiple light source forming me~~ans,~~mber whereby the uniformity in illuminance and the uniformity in numerical aperture can be satisfied at the same time.

Page 7, lines 19-26 and Page 8, lines 1-16:

In the fourth aspect of the present invention, the above-mentioned effects can be obtained when each micro lens of the optical integrator has at least one aspheric refractive surface even if the condition concerning the entrance surface and exit surface in accordance

with the first aspect of the present invention is not satisfied. That is to say, the illumination optical apparatus in accordance with the fourth aspect of the present invention is aimed at satisfying the uniformity in illuminance on the surface to be illuminated and the uniformity in numerical aperture at the same time, and may comprise light source~~means~~ for supplying illumination light, multiple light source forming me~~ans~~mber for forming a number of light sources according to a beam from the light source ~~means~~, and a condenser optical system for guiding beams from the light sources to the surface to be irradiated or a surface optically conjugate with the surface to be irradiated; wherein the multiple light source forming me~~ans~~mber has a wavefront dividing type optical integrator comprising a number of micro lens elements, each micro lens element in the wavefront dividing type optical integrator having at least one refractive surface formed into an aspheric form which is symmetrical about an axis parallel to a reference optical axis in order to attain a substantially uniform illuminance on the surface to be irradiated.

Page 8, lines 24-26 and Page 9, lines 1-8:

The illumination optical system may be characterized in that it comprises a filter having a predetermined optical transmissivity distribution disposed near the optical integrator on the entrance side thereof in order to correct unevenness in illumination on the surface to be irradiated; and positioning ~~means~~sub-system, connected to the optical integrator and the filter, for positioning the optical integrator and filter with respect to each other. In this case, it is preferred that the positioning ~~means~~sub-system have an alignment mark formed in the wavefront dividing type optical integrator and an alignment mark formed in the filter.

Page 9, lines 25-26 and Page 10, lines 1-12:

The illumination optical apparatus may comprise positioning ~~means~~sub-system, connected to at least two of the optical element bundles, for positioning at least two of the optical element bundles with respect to each other. In this case, it is preferred that the

positioning ~~means~~sub-system have respective alignment marks formed in at least two of optical element bundles. Preferably, a filter having a predetermined optical transmissivity distribution for correcting unevenness in illuminance on the surface to be irradiated is disposed near the wavefront dividing type optical integrator on the entrance side thereof, and the positioning ~~means~~sub-system has an alignment mark formed in the filter in order to position at least two of the optical element bundles and the filter with respect to each other.

Page 10, lines 15-22:

The illumination optical apparatus may have light source image enlarging me~~ans~~mber, disposed in the optical path between the optical integrator and the light source~~means~~ at or near a position conjugate with the surface to be irradiated, for enlarging the light source image. Employing a configuration having light source image enlarging me~~ans~~mber as such reduces damages to optical members in the illumination optical apparatus.

Page 10, lines 23-26:

In the illumination optical apparatus, the divergent angle of beams by way of the light source image enlarging me~~ans~~mber may be determined such that no loss in illumination light occurs in the optical integrator.

Page 11, lines 1-8:

The illumination optical apparatus may be characterized in that the optical integrator has a plurality of lens surfaces, arranged two-dimensionally, each forming the light source image; the light source image enlarging me~~ans~~mber enlarges the light source image formed by way of the lens surface; and the divergent angle of the light source image enlarging me~~ans~~mber is set such that the enlarged light source image is smaller than the lens surface.

Page 11, lines 12-15:

The illumination optical apparatus may be characterized in that a substantially uniform illuminance distribution is formed in a near field of the light source image enlarging me~~ans~~mber.

Page 11, lines 16-18:

The illumination optical apparatus may be characterized in that only one pattern is formed in a far field of the light source image enlarging me~~ans~~mber.

Page 11, lines 19-21:

In the illumination optical apparatus, the far field pattern of the light source image enlarging me~~ans~~mber may be circular, elliptical, or polygonal.

Page 12, lines 2-6:

The illumination optical apparatus may further comprise a diffractive optical element, disposed between the light source~~means~~ and the optical integrator, for controlling a form of the secondary light source formed at the pupil of the illumination optical apparatus.

Page 12, lines 7-12:

The illumination optical apparatus may have zeroth-order light blocking me~~ans~~mber, disposed between the diffractive optical element for controlling the form of the secondary light source and the optical integrator, for blocking zeroth-order light from the diffractive optical element for controlling the form of the secondary light source.

Page 12, lines 13-18:

In the illumination optical apparatus, the optical integrator may comprise a plurality of lens surfaces arranged two-dimensionally and an entrance-side cover glass disposed on the entrance side of the plurality of lens surfaces, the entrance-side cover glass being provided with the zeroth-order light blocking me~~ans~~mber.

Page 12, lines 17-21:

In the illumination optical apparatus, the light source image enlarging me~~ans~~mber may have a diffractive optical element or diffuser.

Page 13, lines 8-14:

The illumination optical apparatus may comprise a micro fly's eye lens(micro fly's eye ~~lens~~optical member), disposed in the optical path between the light source~~means~~ and the surface to be irradiated, comprising a substrate having a surface formed with a plurality of lens surfaces, the lens surfaces of the micro fly~~'~~'s eye lens being provided with an antireflection film with respect to the illumination light.

Page 13, lines 15-20:

The illumination optical apparatus may comprise illuminance distribution correcting me~~ans~~mber, disposed between the light source~~means~~ and the optical integrator, for controlling respective intensity distributions of Fourier-transformed images of the plurality of light source images independently from each other.

Page 13, lines 21-26 and Page 14, lines 1-2:

In the illumination optical apparatus, the optical integrator may comprise a plurality of lens surfaces arranged two-dimensionally, an entrance-side cover glass disposed on the entrance side of the plurality of lens surfaces, and an exit-side cover glass disposed on the exit side of the plurality of lens surfaces, the illuminance distribution correcting me~~ans~~mber being disposed in an optical path between the entrance-side cover glass and the exit-side cover glass.

Page 15, lines 9-11:

In the illumination optical apparatus, the light source~~means~~ may supply illumination light having a wavelength of 200 nm or shorter.

Page 15, lines 12-14:

In the illumination optical apparatus, the diffractive optical element or micro fly's eye lens may have silica glass doped with fluorine.

Page 15, lines 15-23:

The illumination optical apparatus in accordance with a fifth aspect of the present invention is an illumination optical apparatus for illuminating a surface to be irradiated with a beam from a light source, the apparatus including a plurality of optical elements disposed in an optical path between the light source and the surface to be irradiated, at least one of the optical elements comprising positioning ~~means~~sub-system, provided in the at least one optical element, for optically positioning the at least one optical element.

Page 15, lines 24-26:

In the illumination optical apparatus, the positioning ~~means~~sub-system may be disposed outside the optical path between the light source and the surface to be irradiated.

Page 16, lines 1-17:

The illumination optical apparatus in accordance with a sixth aspect of the present invention is an illumination optical apparatus for illuminating a surface to be irradiated with illumination light from a light source, the apparatus comprising a micro fly's eye lens, disposed in an optical path between the light source and the surface to be irradiated, having a substrate with a surface formed with a plurality of lens surfaces; and a condenser optical system, disposed in an optical path between the micro fly's eye lens and the surface to be irradiated, for guiding a beam from the micro fly's eye lens to the surface to be irradiated or a surface optically conjugate with the surface to be irradiated, the lens surfaces of the micro fly's eye lens being provided with an antireflection film with respect to the illumination light. When the antireflection film is provided as such, the efficiency of illumination onto the surface to be irradiated can be improved.

Page 17, lines 19-26 and Page 18, lines 1-15:

The illumination optical apparatus in accordance with a seventh aspect of the present invention is an illumination optical apparatus for illuminating a surface to be irradiated with illumination light from a light source, the apparatus comprising a micro fly~~'~~’s eye lens, disposed in an optical path between the light source and the surface to be irradiated, having a substrate with a surface formed with a plurality of lens surfaces; a condenser optical system, disposed in an optical path between the micro fly~~'~~’s eye lens and the surface to be irradiated, for guiding a beam beam from the micro fly's eye lens to the surface to be irradiated or a surface optically conjugate with the surface to be irradiated; and an exit-side protecting member disposed on the exit side of the micro fly~~'~~’s eye lens and formed from a material transparent to the illumination light, the exit-side protecting member having a light-shielding member, provided in the exit-side protecting member, for blocking light passing through a region of the micro fly~~'~~’s eye lens different from the plurality of lens surfaces toward the surface to be irradiated. If the light-shielding member is provided as such, so as to block the light passed through the region of micro fly's eye lens different from the lens surfaces, then image forming performances can be improved.

Page 18, lines 16-18:

In the illumination optical apparatus, the optical integrator may comprise an entrance-side cover glass disposed on the entrance side of the micro fly~~'~~’s eye lens.

Page 18, lines 19-26 and Page 19, lines 1-12:

The illumination optical apparatus in accordance with an eighth aspect of the present invention is an illumination exposure apparatus, adapted to be combined with a photolith~~ograp~~grahic exposure apparatus comprising a projection optical system by which an image of a pattern on a mask disposed at a first surface is formed on a photosensitive substrate disposed at a second surface, for illuminating the first surface with a beam from a

light source, the illumination optical apparatus comprising multiple beam superimposing me~~ans~~mber, disposed between the light source and the first surface, for dividing the beam from the light source and superimposing thus divided number of beams on an illumination field which is a region on a predetermined surface; and an illumination image forming optical system, disposed between the multiple beam super~~imposing means~~posing member and the first surface, for forming an image of the illumination field on or near the first surface, the illumination image forming optical system having an aperture stop disposed at a position optically conjugate with a pupil of the projection optical system.

Page 19, lines 13-15:

In the illumination optical apparatus, the multiple beam super~~imposing means~~posing member may divide a wavefront of the beam from the light source.

Page 19, lines 16-21:

The exposure apparatus in accordance with a ninth aspect of the present invention is a photolith~~ograp~~grahic exposure apparatus for projecting a pattern of a mask onto a photosensitive substrate, the apparatus comprising the illumination optical apparatus, the surface to be irradiated being set on the photosensitive substrate.

Page 20, lines 4-17:

The exposure apparatus in accordance with a tenth aspect of the present invention is a photolith~~ograp~~grahic exposure apparatus for transferring a pattern of a mask disposed on a first surface onto a workpiece disposed on a second surface, the exposure apparatus comprising the illumination optical apparatus for illuminating the first surface; and a projection exposure apparatus, disposed in an optical path between the first and second surfaces, for projecting the pattern of the mask onto the workpiece, the illumination optical apparatus further comprising optical intensity distribution changing me~~ans~~mber, disposed in

the optical path between the light source and the optical integrator, for changing an optical intensity distribution of a beam incident on the optical integrator.

Page 20, lines 18-25:

The exposure apparatus in accordance with an eleventh aspect of the present invention is a photolith~~ograpgra~~hic exposure apparatus for illuminating a mask formed with a pattern with illumination light in a predetermined wavelength range so as to form an image of the pattern onto a substrate by way of a projection optical system, the exposure apparatus comprising the illumination optical apparatus for supplying the illumination light to the mask.

Page 21, lines 6-18:

The exposure method in accordance with a twelfth aspect of the present invention is an exposure method in which a mask formed with a pattern is illuminated with illumination light in a predetermined wavelength range so as to form an image of the pattern onto a substrate by way of a projection optical system, wherein the illumination light is supplied to the mask by use of the illumination optical apparatus. When the illumination optical apparatus is used as such, projection/exposure can be carried out under a favorable exposure condition, whereby favorable micro devices (semiconductor device, image pickup device, liquid crystal display picking device, thin film magnetic head, and the like) can be made.

Page 26, lines 1-3:

Fig. 12A is a view showing the configuration of each micro fly's eye lens of multiple light source forming me~~ans~~mber along an optical axis AX;

Page 26, lines 4-5:

Fig. 12B is a view showing operations and cross-sectional forms of a pair of micro fly~~'s eye~~'s eyes lenses;

Page 26, lines 6-7:

Fig. 13 is a view for explaining positioning of a pair of micro fly~~'s eye~~'s eyes lenses;

Page 26, lines 11-12:

Fig. 14B is a view showing a turret provided with micro fly~~'s eye~~'s eyes lenses;

Page 26, lines 15-16:

Fig. 15A is a view showing an embodiment of diffractive optical element as light source image enlarging me~~ans~~mber;

Page 26, line 17:

Fig. 15B is a plan view of a micro fly~~'s eye len~~'s eye lenses;

Page 26, lines 18-19:

Fig. 16 is a view for explaining functions of micro fly~~'s eye~~'s eyes lenses;

Page 27, lines 20-23:

Fig. 17A is a view for explaining a function of a diffractive optical element as light source image enlarging me~~ans~~mber;

Page 27, lines 1-3:

Fig. 18 is a view for explaining a function of a diffractive optical element as light source image enlarging me~~ans~~mber;

Page 27, lines 4-5:

Fig. 19A is a view for explaining an effect of light source image enlarging me~~ans~~mber;

Page 27, lines 6-7:

Fig. 19B is a view for explaining an effect of light source image enlarging me~~ans~~mber;

Page 36, lines 10-26 and Page 37, lines 1-2:

The illumination optical apparatus included in the microscope in accordance with the first embodiment will now be explained with reference to Fig. 6A. Fig. 6A is a view schematically showing the configuration of the illumination optical apparatus included in the microscope. The illumination optical apparatus is equipped with a halogen lamp 10, for example, as a light source for supplying illumination light. A beam from the halogen lamp 10 is turned into a substantially parallel beam by way of a collimator lens 11 and is made incident on a micro fly's eye lens 12 acting as a wavefront dividing type optical integrator. As shown in Figs. 1 and 5, the micro fly's eye lens 12 is an optical element composed of a number of micro lenses densely arranged in a matrix, each having a positive refracting power, whereas the entrance surface and exit surface of each micro lens have regular hexagonal forms with the same size (size d). The micro fly's eye lens 12 is constructed, for example, by etching a plane-parallel glass sheet so as to form a micro lens group.

Page 37, lines 2-21 and Page 38, lines 1-4:

Hence, the beam incident on the micro fly's eye lens 12 is two-dimensionally divided by a number of micro lenses, so that a substantial surface light source (hereinafter referred to as "secondary light source") composed of a number of light sources is formed at the image-side focal plane of the micro fly's eye lens 12. The beam from the secondary light source formed at the image-side focal plane of the micro fly's eye lens 12 is restricted by an aperture stop 13 disposed in the vicinity thereof and then is collected by a condenser lens 14, so as to form an illumination field at the image-side focal plane of the condenser lens 14. A field stop 15 is located at a position where the illumination field is formed (i.e., the image-side focal plane of the condenser lens 14). Thus, the collimator lens 11, micro fly's eye lens 12, and condenser lens 14 constitute multiple beam superimposing me~~ans~~mber for forming a number of light sources according to the beam from the light source 10 and forming an illumination

field which is a region on a predetermined surface where beams from the light sources are superimposed.

Page 39, lines 6-22:

In the illumination optical apparatus included in the microscopes of the first and second embodiments, the micro fly's eye lens 12 is configured so as to satisfy the above-mentioned conditional expression (1). Therefore, in the illumination field formed at the position of the field stop 15 ~~,and~~and, consequently, in the illumination area (illumination field) formed at the object surface 17, which is a surface to be irradiated, the width of marginal areas where illuminance decreases can be kept small, so that a uniform illuminance distribution can be obtained substantially over the whole illumination area. If the micro fly's eye lens 12 is configured so as to satisfy the above-mentioned conditional expression (1'), then the width of marginal areas where illuminance decreases can be kept smaller, so that a further uniform illuminance distribution can be obtained substantially over the whole illumination area.

Page 39, lines 23-26 and Page 40, lines 1-12:

Third Embodiment

Fig. 8 is a view schematically showing the configuration of a photolithographic exposure apparatus in accordance with a third embodiment of the present invention. The exposure apparatus employs an super-high pressure mercury lamp as its light source, and is used for making a liquid crystal display device. The exposure apparatus in accordance with the third embodiment is equipped with a light source 20 comprising an super-high pressure mercury lamp supplying light including an emission line of i-line, for example. The light source 20 is positioned at a first focal position of an elliptical mirror 21 having an elliptical reflecting surface which has rotational symmetry about an optical axis AX. As a

consequence, an illumination beam emitted from the light source 20 forms a light source image at a second focal position of the elliptical mirror 21.

Page 40, lines 24-26 and Page 41, lines 1-14:

In the optical integrator 23, as shown in Fig. 8, a plane-parallel plate 23c having a predetermined thickness is interposed between a first micro lens group (bundle) 23a on the entrance side and a second micro lens group (bundle) 23b on the exit side, and they are integrally constructed. Here, the first micro lens group 23a on the entrance side is composed of a number of rectangular (d_1 x d_2) micro lenses, each having a positive refracting power, densely arranged in a matrix as shown in Fig. 2A. On the other hand, the second micro lens group 23b is composed of a number of regular hexagonal (size D) micro lenses, each having a positive refracting power, densely arranged in a matrix as shown in Fig. 2B. The first micro lens group 23a on the entrance side and the second micro lens group 23b on the exit side are formed by a mold method, for example, such that respective optical axes of micro lenses corresponding to each other strictly align with each other.

Page 42, line 17-26 and Page 43, lines 1-11

As a consequence, a beam collected by way of the condenser lens 25 illuminates, in a superimposing manner, an illumination field stop 26 for defining the illumination area (illumination field) of a mask M which will be mentioned later. The beam having passed through a rectangular opening portion of the illumination field stop 26 illuminates, in a superimposing manner by way of an image forming optical system 27, the mask M formed with a predetermined transfer pattern. Thus, an image of the opening portion of the illumination field stop 26, i.e., a rectangular illumination area similar to the cross-sectional form of the first micro lenses of the optical integrator 23, is formed on the mask M. An aperture stop 28 for blocking unnecessary light which causes flare and the like is disposed near the pupil plane of the image forming optical system 27 (a position optically conjugate

with the entrance pupil plane of the projection optical system PL). Such use of aperture stop 28 is applicable not only to an illumination apparatus using a micro fly's eye lens as with this embodiment, but also to illumination optical apparatus using an internal reflection type integrator.

Page 44, lines 17- 26 and Page 45, lines 1-5:

In the exposure apparatus in accordance with the third embodiment, the optical integrator 23 is configured so as to satisfy at least one of the above-mentioned conditional expressions (2) and (3). Therefore, in the illumination area (exposure area) formed on the mask M that is the surface to be irradiated ~~, and~~and, consequently, on the plate P, the width of marginal portions where illuminance decreases can be kept small, whereby a uniform illumination distribution can be obtained substantially over the whole illumination area. If the optical integrator 23 is configured so as to satisfy at least one of conditional expressions (2') and (3'), then the width of marginal portions where illuminance decreases can be kept smaller, whereby a further uniform illumination distribution can be obtained substantially over the whole illumination area.

Page 46, lines 11-25:

Fourth Embodiment

Fig. 9 is a view showing the configuration of the exposure apparatus in accordance with a fourth embodiment of the present invention. In the exposure apparatus in accordance with the fourth embodiment, the present invention is applied to a photolithographic exposure apparatus using an excimer laser light source for making a semiconductor device. The exposure apparatus is equipped with an excimer laser light source for supplying light having a wavelength of 248 nm (KrF) or 193 nm (ArF), for example, as a light source 30 for supplying exposure light (illumination light). A substantially parallel beam emitted from the light

source 30 is shaped into a beam having a predetermined rectangular cross section by way of a beam expander (not depicted) and then is made incident on a micro fly's eye lens 31.

Page 46, line 1 and Page 47, lines 1-11:

The micro fly's eye lens 31 is composed of a number of square micro lenses, each having a positive refracting power, densely arranged in a matrix. Thus, a number of light sources are formed at the image-side focal plane of the micro fly's eye lens 31. Beams from a number of light sources formed at the image-side focal plane of the micro fly's eye lens 31 are made incident on a wavefront dividing type optical integrator 33 by way of a first condenser lens 32. As shown in Fig. 9, the optical integrator 33 is constituted by a first micro fly's eye lens 33a disposed on the entrance side and a second micro fly's eye lens 33b disposed on the exit side.

Page 47, lines 12-25:

Here, as shown in Fig. 4, each of the first micro fly's eye lens 33a on the entrance side and the second micro fly's eye lens 33b on the exit side is composed of a number of rectangular micro lenses, each having a positive refracting power, densely arranged in a matrix. Also, each of first micro lenses constituting the first micro fly's eye lens 33a on the entrance side and each of second micro lenses constituting the second micro fly's eye lens 33b on the exit side have rectangular (d_1 x d_2) forms with the same size. Further, the first micro fly's eye lens 33a and the second micro fly's eye lens 33b are positioned with respect to each other such that the optical axis of each first micro lens strictly aligns with the optical axis of its corresponding second micro lens.

Page 47, line 1and Page 48, lines 1-18:

In this case, a micro lens constituting the optical integrator 33 is constituted by a first micro lens constituting the first micro fly's eye lens 33a on the entrance side and a second micro lens constituting the second micro fly's eye lens 33b on the exit side. The focal length

of each micro lens constituting the optical integrator 33 is a composite focal length of the above-mentioned first and second micro lenses. It is preferred that cover glasses be disposed on the entrance side and exit side of the optical integrator 33. Also, the radius of curvature of the first micro lenses constituting the first micro fly's eye lens 33a and that of the second micro lenses constituting the second micro fly's eye lens 33b may be made slightly different from each other, so that the object-side focal position coincides with the entrance surface of the first micro fly's eye lens 33a while the image-side focal position thereof resides in a space on the exit side of the second micro fly's eye lens 33b. In this case, there are advantages from the viewpoints of light energy quantity and endurance to laser.

Page 48, lines 19-26:

A specific numerical example of first and second micro lenses constituting the first and second fly's eyes lens 33a, 33b (micro lenses constituting the optical integrator 33) will now be explained. In the following numerical example, as a mode advantageous in terms of light energy quantity and endurance to laser, the curvature of the outermost exit-side lens surface among the four lens surfaces is set to a value different from that of the other lens surfaces.

Page 50, lines 7-9:

~~Namely~~That is, a uniform illuminance distribution can be obtained substantially over the whole illumination field formed in the above-mentioned numerical example.

Page 53, lines 6-18:

Meanwhile, when carrying out scan exposure in the exposure apparatus in accordance with the fourth embodiment, the illuminance distribution along the scanning direction (the direction optically corresponding to the shorter-side direction of the rectangular entrance surface of the optical integrator 33) is averaged smoothed by an action of the scan exposure, whereby it is preferred that conditional expression (6) concerning the longer-side direction of

the rectangular entrance surface of the optical integrator 33 in conditional expressions (6) and (7) be satisfied. Similarly, when carrying out scan exposure in the fourth embodiment, it is further preferred that conditional expression (6') be satisfied.

Page 54, lines 9-13:

Though the present invention is applied to illumination optical apparatus for microscopes and photolithographic exposure apparatus in the above-mentioned embodiments, they are not restrictive, and the present invention is also applicable to other common illumination optical apparatus.

Page 55, lines 11-20:

Fifth Embodiment

The projection exposure apparatus in accordance with a fifth embodiment of the present invention will now be explained with reference to Fig. 11. Fig. 11 is a view schematically showing a lithographic projection exposure apparatus equipped with an illumination optical apparatus in accordance with an embodiment of the present invention. In the projection exposure apparatus shown in Fig. 11, the illumination optical apparatus is set so as to carry out conventional circular illumination.

Page 58, lines 3-13:

The circular divergent beam having traveled by way of the diffractive optical element 131 is transmitted through a zoom lens 104 acting as a first condenser optical system, and is made incident on multiple light source image forming me~~ans~~mber 105 constituted by a pair of micro fly's eye lenses 151 and 152. Thus, a circular illumination field is formed at the entrance surface of the multiple light source image forming me~~ans~~mber 105 (i.e., the entrance surface of the micro fly's eye lens 151 on the light source side). The size of thus formed illumination field (i.e., its diameter) varies depending on the focal length of the zoom lens 104.

Page 58, line 1 and Page 59, lines 1-5:

Fig. 12A is a view showing the configuration of multiple light source image forming me~~ans~~mber included in a projection exposure apparatus, illustrating the configuration of each micro fly's eye lens as seen along the optical axis AX, whereas Fig. 12B is a view showing operations and cross-sectional forms of a pair of micro fly's eye lenses.

Page 60, lines 16-25:

Hence, a number of light sources (hereinafter referred to as "secondary light source") having a circular form identical to that of the illumination field formed at the entrance surface of the micro fly's eye lens 151 on the light source side are formed at the image-side focal plane of the pair of micro fly's eye lenses 151 and 152. Thus, the pair of micro fly's eye lenses 151 and 152 constitute one wavefront dividing type optical integrator ~~,and~~ and, consequently, multiple light source forming me~~ans~~mber 105 for forming a number of light sources according to a beam from the light source 101.

Page 65, lines 14-18:

~~If~~When the focal length of zoom lens 107 is set to a predetermined value, then it is possible for this embodiment to obtain a desirable size of illumination area on the mask 110~~,~~, and consequently, a desirable size of exposure area on the wafer 112.

Page 65, lines 19-24:

If the focal length of zoom lens 104 is set to a predetermined value with respect to the focal length of zoom lens set at a predetermined value, then a desirable size of illumination NA can be obtained on the mask 110~~,and~~, and consequently, it can be set or adjusted to a desirable ó value.

Page 66, lines 16-25:

The diffractive optical element 132 for annular modified illumination converts a parallel beam having a rectangular cross section incident along the optical axis AX into a~~n~~

annular divergent beam. The annular divergent beam obtained by way of the diffractive optical element 132 is transmitted through the zoom lens 104 and then is made incident on the pair of micro fly's eye lenses 151 and 152. Thus, a~~n~~ annular illumination field is formed at the entrance surface of the micro fly's eye lens 151 on the light source side. As a result, a second light source having a~~n~~ annular form identical to that of the illumination field formed at the entrance surface of the micro fly's eye lens 151 on the light source side is formed at the image-side focal plane of the pair of micro fly's eye lenses 151 and 152, whereby annular modified illumination can be carried out according to the beam from this annular secondary light source.

Page 67, lines 17-20:

Thus, the diffractive optical elements 131 to 133 constitute optical intensity distribution changing me~~ans~~mber for changing the optical intensity distribution of the beam incident on the multiple light source forming me~~ans~~mber 105.

Page 68, lines 9-26 and Page 69, lines 1-4:

In this embodiment, at least one of the above-mentioned four refractive surfaces m1 to m4 is formed into an aspheric surface which is symmetrical about an axis (center axis) parallel to the optical axis AX. Since the number of parameters in terms of optical designing increases as the aspheric surface is introduced in this case, it becomes easier to yield a desirable design solution, whereby the degree of freedom in design improves remarkably from the viewpoint of aberration correction in particular. Consequently, in a combining optical system composed of a pair of micro lens elements 151a and 152a, not only spherical aberration is favorably restrained from occurring, but also the occurrence of coma can favorably be suppressed as the sine condition is substantially satisfied. As a result, in this embodiment, the multiple light source image forming me~~ans~~mber 105 constituted by the pair of micro fly's eye lenses 151 and 152 substantially satisfies the sine condition, so as to

favorably restrain the unevenness in illumination from occurring due to the multiple light source forming ~~means~~mber 105, whereby the uniformity in illuminance in the surface to be irradiated and the uniformity in numerical aperture can be satisfied at the same time.

Page 69, lines 19-26 and Page 70, lines 1-3:

As mentioned above, the four refractive surfaces m1 to m4 are formed into aspheric surfaces having properties identical to each other. The aspheric surfaces are represented by the following expression:

$$S(y) = (y^2/r) / \{ 1 + (1 - \kappa \cdot y^2/r^2)^{1/2} \}$$

where y is the height in a direction perpendicular to the center axis, S(y) is the distance (sag amount) along the center axis from the tangent plane of the apex of each aspheric surface at the height y to the respective aspheric surface, r is the reference radius of curvature (radius of apex curvature), and ê is the conical coefficient.

Page 70, lines 18-26:

In the multiple light source forming ~~means~~mber 105 composed of thus configured pair of micro fly's eye lenses 151 and 152, spherical aberration becomes –0.025, the sine condition unsatisfying amount becomes -0.002, and coma becomes –0.005. That is, it can be seen that the above-mentioned numerical example introducing aspheric surfaces not only restrains spherical aberration from occurring, but also favorably suppresses the occurrence of coma by substantially satisfying the sine condition.

Page 71, lines 1-19:

In Fig. 12A, the diameter of the circular area 150b formed with the micro lens elements 150c is defined so as to correspond to the maximum ó value to be set, and is set to about 86 mm, for example. As a consequence, when the size of micro lens element 150c is set to 0.54 mm x 0.2 mm as indicated in the above-mentioned numerical example, then the

effective number of micro lens elements 150c formed within the circular area 150b becomes about 50,000. In this case, a very large wavefront dividing effect is obtained in the multiple light source forming me~~ans~~mber 105, whereby the occurrence of unevenness in illuminance can be reduced on the mask 110, which is the surface to be irradiated, or on the wafer 112. As a result, fluctuations in the unevenness in illuminance and changes in telecentricity can be kept very low even when switching illumination conditions (switching among circular illumination, annular modified illumination, and quadrupolar illumination, changing of illumination parameters such as the size of illumination area and ó value, and the like).

Page 71, lines 20-26 and Page 72, lines 1-10:

Since a very large wavefront dividing effect is obtained in the multiple light source forming me~~ans~~mber 105, it becomes unnecessary for an illumination aperture stop having ~~an~~ annular opening portion or a quadrupolar (generally multipolar) opening portion to be disposed at the position of iris stop 106 upon annular modified illumination or quadrupolar modified illumination. That is, even when switching is to be carried out among circular illumination, annular modified illumination, and quadrupolar illumination, it will be sufficient if the opening diameter of iris stop 106 is changed as necessary so as to block unnecessary beams such as flare light, without synchronously carrying out the switching among circular illumination, annular modified illumination, and quadrupolar illumination as in the prior art. In other words, arrangement of an illumination aperture stop known as ó stop may be omitted, whereby the configuration can be simplified.

Page 72, lines 11-22:

For yielding a sufficient wavefront dividing effect in the present invention, it is preferred that the effective number of micro lens elements constituting one micro fly's eye lens be 1,000 or greater. For further enhancing the wavefront dividing effect, it is preferred

that the effective number of micro lens elements be 50,000 or greater. Here, the effective number of micro lens elements constituting one micro fly's eye lens corresponds to the number of combining optical systems and the number of center axes (optical axes) of individual micro lens elements parallel to the optical axis AX~~.~~, and consequently, the number of wavefront divisions of multiple light source forming me~~ans~~mber 105.

Page 72, lines 23-26 and Page 73, lines 1-11:

Meanwhile, in this embodiment, since the multiple light source forming me~~ans~~mber 105 is constituted by a pair of micro fly's eye lenses 151 and 152, whereas the size and focal length of each micro lens element are very small, it is important for a pair of micro lens elements which should correspond to each other along the optical axis AX to be positioned with respect to each other, i.e., for the pair of micro fly's eye lenses 151 and 152 to be positioned with respect to each other. Specifically, it is necessary for a pair of micro lens elements which should correspond to each other to be positioned without two-dimensionally translating their positions within a plane orthogonal to the optical axis AX and without rotating their positions about the optical axis AX within a plane orthogonal to the optical axis AX.

Page 73, lines 12-22:

As shown in Fig. 12A, each of the micro fly's eye lenses ~~151 and 152~~ therefore is formed with four alignment marks 150d acting as means for positioning the pair of micro fly's eye lenses 151 and 152 in this embodiment. The four alignment marks 150d are formed by depositing chromium, for example, at positions corresponding to the four corners of a square outside the circular area 150b formed with a number of micro lens elements 150c, i.e., outside the illumination optical path. Each alignment mark 150d is formed with a positional precision of about 1 ì m, for example, while having a size of about 2 mm.

Page 74, lines 11-26:

Upon positioning the pair of micro fly's eye lenses 151 and 152 with respect to each other, the four alignment marks formed in the micro fly's eye lens 151 and the four alignment marks formed in the micro fly's eye lens 152 are observed with unaided eye~~-~~(naked eye) or through a loupe or microscope. Then, at least one of a pair of holding members 155 is minutely moved by the driving system 156 such that alignment marks 150d corresponding to each other align with each other along the optical axis AX. Thus, the pair of micro fly's eye lenses 151 and 152 can be positioned with respect to each other~~,~~, and consequently, a pair of micro lens elements which should correspond to each other along the optical axis AX can be positioned with respect to each other. Here, both of the pair of holding members 155 may be made movable, or one of the pair of holding members 155 may be made movable while the other is fixed.

Page 75, lines 1-15:

Another positioning method may be employed in which an angle measuring device such as autocollimator, for example, is used for observing the positional deviation between a pair of micro lens elements corresponding to each other. In this case, after the autocollimator is initially set while in a state where the pair of micro fly's eye lenses 151 and 152 are not inserted in the illumination optical path, the pair of micro fly's eye lenses 151 and 152 are inserted into the illumination optical path, and the positioning is carried out according to a beam transmitted through the pair of micro lens elements. Also employable is a method in which a beam transmitted through the pair of micro lens elements is observed with a microscope or the like, and the positional deviation of the pair of micro lens elements observed within its field of view is read o~~ut~~ff, so as to carry out positioning.

Page 75, lines 16-26 and Page 76, lines 1-12:

In an illumination optical apparatus such as that of this embodiment, it has been known that unevenness in illuminance occurs due to angular characteristics of antireflection films applied to individual lenses constituting the zoom lens 107 acting as a condenser optical system. Here, an antireflection film is formed by depositing a plurality of thin dielectric films onto a lens surface, and eliminates reflected light by dividing the reflected light in terms of amplitude and causing a number of light components to interfere with each other with their phases being shifted from each other. Since the shifting of phases is regulated depending on the film thickness, the antireflection effect may vary when the indcidence angle of beam changes. In general, light beams transmitted through more marginal areas of a lens are bent more greatly in an optical system using the lens, whereby the angle of incidence becomes greater. On the other hand, antireflection films are designed for vertical incidence, whereby light having a greater angle of incidence is more likely to be reflected. As a result, illuminance tends to decrease substantially like a quadratic curve as the image height is higher in the surface to be irradiated, i.e., as the position is farther from the optical axis.

Page 78, lines 7-14:

Though a pair of micro fly's eye lenses disposed with a gap therebetween constitute multiple light source forming me~~ans~~mber in the above-mentioned embodiment, at least two optical element bundles disposed with a gap therebetween can also constitute multiple light source forming me~~ans~~mber in general. Here, an optical element bundle is a concept encompassing two-dimensional arrays of lens surfaces and two-dimensional arrays of reflecting surfaces.

Page 78, lines 15-18:

While micro fly's eye lenses are formed by etching in the above-mentioned embodiment, they may also be formed by a denting~~-~~(an impressing) technique or a grinding technique, for example.

Page 79, lines 8-16:

Though the fifth embodiment is configured such that diffractive optical elements acting as optical intensity distribution changing me~~ans~~mber are positioned in the illumination optical path in a turret fashion, a known slider mechanism, for example, may be utilized so as to switch the above-mentioned diffractive optical elements. Meanwhile, detailed explanations concerning diffractive optical elements which can be utilized in the present invention are disclosed in USP 5,850,300 and the like.

Page 79, lines 17-21:

Though diffractive optical elements are used as optical intensity distribution changing me~~ans~~mber in the above-mentioned embodiment, wavefront dividing type optical integrators such as fly's eye lens and micro fly's eye lens, for example, may also be used.

Page 80, lines 5-9:

Though the above-mentioned embodiment illustrates an example in which a quadrupolar secondary light source is formed, a bipolar secondary light source (having two ~~eye~~illuminants) or multipolar secondary light sources such as octapolar ~~on~~secondary light source (having eight ~~eye~~illuminants) may also be formed.

Page 81, lines 11-23:

Sixth Embodiment

The projection exposure apparatus in accordance with a sixth embodiment of the present invention will be explained with reference to Fig. 14A. Fig. 14A is a view schematically showing the configuration of a projection exposure apparatus equipped with an illumination optical apparatus in accordance with an embodiment of the present invention. In Fig. 14A, Z axis is set along the normal direction of a wafer W which is a substrate (work~~piece~~) coated with a photosensitive material, Y axis is set in a direction parallel to the

paper surface of Fig. 14A within the wafer surface, and X axis is set in a direction perpendicular to the paper surface of Fig. 14A within the wafer surface.

Page 83, lines 4-7:

The beams timewise divided into incoherent multiple pulses by way of the optical delay unit 202 with time are directed to a turret 230 provided with a plurality of micro fly's eye lenses(micro fly's eye optical member) 231, 232.

Page 83, lines 25-26 and Page 8, lines 1-15:

Returning to Fig. 14A, a plurality of lens surfaces of the micro fly's eye lens 231 for annular illumination collect the beam from the light source 201 by way of the optical delay unit 202, so as to form a plurality of light source images (which are real ~~and~~or virtual images when the refracting power of lens surface is positive or negative, respectively), whereby a divergent beam having a predetermined divergent angle is emitted from the micro fly's eye lens 231. *An afocal zoom optical system 204 is disposed on the exit side of the micro fly's* eye lens 231. The afocal zoom optical system 204 is configured such that its angular magnification is variable, whereby the incident divergent beam is emitted by way of the afocal zoom optical system 204 so as to yield an angle corresponding to the set angular magnification. The beam emitted from the afocal zoom optical system 204 is directed to a turret 250 provided with a plurality of diffractive optical elements 251 to 253.

Page 85, lines 21-26 and Page 86, lines 1-7:

Returning to Fig. 14A, the diffractive optical element 251 for annular illumination is set into the illumination optical path in the case where the micro fly's eye lens 231 for annular illumination is set into the optical path. Since the diffractive optical element 251 is not illuminated with a parallel beam but with a beam having a predetermined angle (numerical aperture) given by the micro fly's eye lens 231 and afocal zoom optical system 204, its far field region is formed with ~~an~~ annular (doughnut-shaped) optical intensity distribution having

a width corresponding to the above-mentioned predetermined angle instead of a ring-shaped optical intensity distribution whose width is substantially zero.

Page 86, lines 9-14:

In the example of Fig. 14A, a zoom optical system 206 subsequent to the diffractive optical element 251 (252, 253) forms its far field region at a finite distance (at or near the image-side focal position of the zoom optical system 206). As a consequence, ~~an~~ annular optical intensity distribution is formed at or near the image-side focal position of the zoom optical system 206.

Page 89, lines 18-24:

As shown in Fig. 15A, the optical integrator 207 of this embodiment has a pair of micro fly's eye lenses 271, 272, an entrance-side cover glass 273 positioned on the entrance side of micro fly's eye lenses, an exit-side cover glass 274 positioned on the exit side of micro fly's eye lenses, and a diffractive optical element 275 acting as light source image enlarging me~~ans~~mber.

Page 92, lines 12-26 and Page 93, lines 1-4:

Here, the secondary light source has a form substantially similar to the cross sectional form of the beam incident on the optical integrator 207, so that, for example, ~~an~~ annular secondary light source is formed at the illumination pupil when the micro fly's eye lens 231 for annular illumination and the diffractive optical element 251 for annular illumination are set into the illumination optical path, and a secondary light source having four rectangular cross sections eccentric with respect to the optical axis (aggregate of four light source images having rectangular cross sections respectively positioned in the first to fourth quadrants in XY coordinates whose origin is located at the optical axis) is formed at the illumination pupil when the micro fly's eye lens 231 for multipolar (quadrupolar) illumination and the diffractive optical element 251 for multipolar (quadrupolar) illumination are set into the illumination

optical path. At the time of conventional illumination, on the other hand, a circular secondary light source is formed at the illumination pupil.

Page 95, lines 12-18:

In the sixth embodiment, the diffractive optical element 275 acting as light source image enlarging me~~ans~~mber hence is disposed on the light source side of the micro fly's eye lens 271 constituting a part of the optical integrator 207. With reference to Figs. 17A to 17C and 18, functions of the diffractive optical element 275 as light source image enlarging me~~ans~~mber will now be explained.

Page 97, line 1 and Page 98, lines 1-10:

In this embodiment, it is preferred that the angle of divergence of the diffractive optical element 275 acting as light source image enlarging me~~ans~~mber be set such that no loss in illumination light occurs in the optical integrator 207. That is, in the case where the optical integrator 207 has a plurality of two-dimensionally arranged micro lens surfaces (271a, 271b, 272a, or 272b) as in this embodiment, it is preferred that the angle of divergence of diffractive optical element 275 be set such that the size of enlarged images SI be smaller than the size of micro lens surfaces (271a, 271b, 272a, or 272b) within XY plane.

Page 99, lines 4-14:

Returning to Fig. 17A, the diffractive optical element 275 as light source image enlarging me~~ans~~mber is disposed such that the entrance-side lens surface 271a of micro fly's eye lens 271 is positioned near the near field region NF of the diffractive optical element 275. ~~Here, s~~Since each of a plurality of entrance-side lens surfaces 271a of micro fly's eye lens 271 is disposed substantially conjugate with the exposure area on the wafer W, there is a fear that the illuminance distribution within the exposure area on the wafer W may become uneven if the illuminance distribution is uneven within the entrance-side lens surface 271a.

Page 99, lines 15-18:

~~Therefore, in~~It is preferable that near field region of the diffractive optical element, as light source image enlarging me~~ans, its near field region preferably~~ mber,has a substantially uniform illuminance distribution.

Page 101, lines 10-21:

Though the diffractive optical element 275 is used as light source image enlarging me~~ans~~mber in the sixth embodiment, it may be either a refraction optical element or a diffuser. Even when a refraction optical element or diffuser is used as light source image enlarging me~~ans~~mber, it is preferred that the range of angle of divergence from the light source image enlarging me~~ans~~mber be set to a desirable value, and that the illuminance distribution of light source image enlarging me~~ans~~mber in the far field region and that in the near field region (or at a position conjugate with the surface to be irradiated in the optical integrator) be substantially uniform.

Page 101, lines 22-26 and Page 101, lines 1-6:

Though the far field pattern formed in the far field region by the light source image enlarging me~~ans~~mber is circular or rectangular in the above-mentioned embodiment as shown in Figs. 17B and 17C, the form of far field pattern is not limited thereto. For example, it may take various forms such as polygonal shapes including rectangular (square or oblong), hexagonal, trapezoidal, rhombic, and octagonal forms, elliptical forms, and arc forms. However, it is preferred that the form of the far field pattern of light source image forming means be similar to that of the illumination area formed at the surface to be irradiated.

Page 102, lines 7-13:

In the above-mentioned embodiment, the condenser optical system 209 for co~~llect~~ndensing light from the secondary light source formed at the exit surface of optical integrator 207 in order to illuminate the illumination field stop 210 in a superimposing

manner is configured such that its projection characteristic becomes Fsinè . Specifically, it satisfies the projection relationship of:

(1) $Y = F \sin\theta$

where F is the focal length of condenser optical system 209, è is the angle of incidence of a principal ray onto the condenser optical system 209 when the object-side focal position of the condenser optical system 209 is an entrance pupil, and Y is the distance from the optical axis to a position at which the principal ray emitted from the condenser optical system 209 is made incident on the surface to be irradiated or a surface conjugate therewith. Though the condenser optical system 209 is a zoom optical system with a variable focal length, it substantially maintains the projection relationship of the above-mentioned expression (1) upon zooming.

Page 103, lines 1-7:

If the secondary light source is approximately considered to be a perfectly diffuse planer illuminant-(perfectly diffuse planer light source) when the condenser optical system 209 is configured as such, then the illuminance and numerical aperture within the XY plane where the illumination field stop 210 is located can be made constant regardless of positions within the XY plane.

Page 103, lines 8-19:

In order for the secondary light source formed by the optical integrator 207 to be approximately considered a ~~complete diffuser light source~~perfectly diffuse planer illuminant in this embodiment, the micro lens surfaces 271a, 271b, 272a, 272b in the optical integrator 207 are formed aspheric, so as to achieve spherical aberration correction and coma correction (fulfillment of sine condition) of the optical ~~fibe~~integrator 207. In this embodiment, illumination beams with a uniform illuminance and uniform numerical aperture reach the

illumination field stop 210~~;~~<u>, </u>and consequently, the uniformity in illuminance and uniformity in numerical aperture can be achieved in the whole exposure area on the wafer W, which is a surface to be irradiated.

Page 105, lines 3-15:

The above-mentioned embodiment comprises the entrance-side cover glass 273 and exit-side cover glass 274 in order to prevent surfaces of the micro fly's eye lenses 271, 272 and the diffractive optical element 275 acting as light source image enlarging me~~ans~~<u>mber</u> from being contaminated upon photochemical reactions. Even when contamination is generated due to a photochemical reaction, it will be sufficient if only a pair of cover glasses 273, 274 are replaced, without replacing a pair of micro fly's eye lenses 271, 272 and the diffractive optical element 275. Preferably, the optical path between the pair of cover glasses 273, 274 is filled with air having a higher degree of cleanness, dry air, and/or an inert gas such as nitrogen or helium.

Page 105, lines 18-25:

Though the diffractive optical element 275 is disposed between the entrance-side cover glass 273 and the micro fly's eye lens 271 in the above-mentioned embodiment, the plane of entrance-side cover glass 273 on the exit side (micro fly's eye lens side) may be formed with a diffractive surface, refractive surface, or light-diffusing surface, so as to provide the exit surface of entrance-side cover glass 273 with light source image enlarging me~~ans~~<u>mber</u>.

Page 105, line 1 and Page 106, lines 1-14:

In the case where, in order to regulate the illumination distribution at the surface to be irradiated (wafer W surface), an optical member (transmissivity distribution adjusting member) for adjusting the transmissivity distribution is disposed in an optical path on the light source side from the optical integrator at a position substantially conjugate with the

surface to be irradiated, it is preferably disposed in an optical path between the entrance-side cover glass 273 and the micro fly's eye lens 271. This can reduce the contamination of transmissivity distribution adjusting member. Preferably, the transmissivity distribution adjusting member is disposed in an optical path between the diffractive optical element 275 acting as light source image enlarging me~~ans~~mber and the micro fly's eye lens 271 (a plurality of lens surfaces arranged in a two-dimensional matrix).

Page 106, lines 1-3 and Page 107, lines 1-4:

Since a position near the entrance surface of the optical integrator 207 is taken as the image-side focal position of the zoom optical system 206 on the entrance side thereof in the above-mentioned embodiment, if a zeroth-order light component is emitted from the diffractive optical elements 251 to 253 due to a manufacture error or the like, then this zeroth-order light component may become noise light.

Page 107, lines 12-17:

In such a case, the exit-side cover glass may be provided with a light-shielding member for blocking the above-mentioned zeroth-order light component and leakage light. A light-shielding member provided in the exit-side ~~side~~ cover glass will now be explained with reference to Figs. 20A and 20B.

Page 107, line 1 and Page 108, lines 1-8:

The optical integrator shown in Fig. 20A comprises, successively from the light entrance side, an entrance-side cover glass 277, a diffractive optical element 275 as light source image enlarging me~~ans~~mber, a fly's eye lens 276 having a plurality of rod-shaped lens elements integrated in a two-dimensional matrix within XY plane, and an exit-side cover glass 278. These optical members are arranged so as to become coaxial with each other along an optical axis indicated by a dash-single-dot line in the drawing.

Page 108, lines 13-20:

As shown in Fig. 20B, the light-shielding pattern 278a is positioned within XY plane so as to cover gaps between a plurality of lens elements constituting the fly's eye lens 276 (only the exit-side lens surface 276b being indicated by broken lines in Fig. 20B). For blocking the zeroth-order light component from the diffractive optical elements 251 to 235, this light-shielding pattern also covers positions in the vicinity of their optical axis.

Page 108, lines 21-26 and Page 109, lines 1-3:

As shown in Fig. 21, a light-shielding pattern 277a may be disposed at a position near the optical axis of the entrance-side cover glass 277 so as to prevent the zeroth-order light component from the diffractive optical elements 251 to 253 from converging at the image-side focal position of the zoom optical system 206 and damaging optical members near the converging point (entrance-side cover glass, micro fly's eye lens 271, and the like) and thin films on the optical members.

Page 119, lines 20-26 and Page 120, lines 1-2:

Though the diffractive optical elements 251 to 253 are used for forming annular, multipolar, and circular secondary light sources without light energy quantity loss in the above-mentioned embodiment, a refraction optical element for forming ~~an~~ annular, multipolar, or circular illumination area in a far field upon a refracting action may be used in place of the diffractive optical elements. An example of such a refraction optical element is disclosed in WO99/49505.

Page 125, lines 13-18:

The projection magnification of the projection optical system may be not only that of reduction but also that of enlargement magnification or one-to-one magnification(unit magnification). As the projection optical system, any of dioptric optical system, catadioptric optical system, and cataptric optical system is employable.

Page 125, lines 23-26 and Page 126, lines 1-2:

When individual optical members and the like in the above-mentioned embodiment are electrically, mechanically, or optically connected together so as to achieve functions such as those mentioned above, a photolith~~ograp~~grahic exposure apparatus in accordance with this embodiment can be assembled.

Page 126, lines 3-16:

If a mask is illuminated with an illumination system IL (illumination step), and a photosensitive substrate is exposed in a scan exposure or batch exposure manner to a transfer pattern formed in a mask by use of a projection optical system PL composed of projection optical modules (exposure step), then a micro device (semiconductor device, liquid crystal display device, thin film magnetic head, or the like) can be made. An example of technique for yielding a semiconductor device as a micro device by forming a predetermined circuit pattern on a wafer or the like acting as a photosensitive substrate (work~~piece~~) by use of the exposure apparatus of the above-mentioned embodiment will now be explained with reference to the flowchart of Fig. 22.

Page 126, lines 17-26:

First, at step 301 of Fig. 22, a metal film is deposited on one lot of wafer. Subsequently, at step 302, a photoresist is applied onto the metal film on this one lot of wafer. Then, at step 303, the exposure apparatus shown in ~~Fig. 1~~above embodiments is used such that an image of a pattern on the mask is successively projected and transferred onto individual shot areas on the one lot of water by way of the projection optical system (projection optical modules) of the exposure apparatus. Thereafter, the photoresist on the one lot of wafer is developed at step 304, and then etching is effected on the one lot of wafer while using the resist pattern as the mask at step 305, whereby a circuit pattern corresponding to the pattern on the mask is formed in each shot area on each wafer. Thereafter, circuit

patterns of upper layers are formed and so forth, whereby a device such as semiconductor device is made. The foregoing semiconductor device making method can yield a semiconductor device having a very fine circuit pattern with a favorable throughput.

Page 129, lines 4-8:

As in the foregoing, the embodiments of present invention can reduce damages to optical members in illumination optical apparatus or improve the efficiency of illumination of illumination optical apparatus, and can improve image forming performances when applied to projection exposure apparatus.